A PRELIMINARY ACCOUNT OF THE GEOLOGY OF THE MIDDLE NORTH COAST DISTRICT OF NEW SOUTH WALES.

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(Plate xvi; one Text-figure.)

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Introduction and Previous Records.

It is proposed in the following pages to give a general account of the geology of the Middle North Coast district of New South Wales. Subsequently special aspects will be discussed in detail, particularly the Upper Palaeozoic succession in the Macleay River district and the Lower Palaeozoic rocks of the Nambucca and Bellinger districts.

In 1845 Mr. C. Hodgkinson reported the occurrence of limestone on the Macleay River above Kempsey. Early maps of New South Wales (C. S. Wilkinson, 1880; E. F. Pittman, 1892) showed areas about Kempsey as Devonian and Silurian. De Koninck (1898) described as probably Devonian some fossils submitted to him by the Rev. W. B. Clarke. Mr. W. S. Dun (1898) stated that these fossils had been collected 40 years before, but were destroyed in the Garden Palace fire in 1882. He (1898) gave a list of Permo-Carboniferous fossils which had been submitted to the Mines Department by Mr. E. W. Rudder. These were said to come from a locality about six miles west of Kempsey.

In 1896 Mr. J. E. Carne collected a few specimens from the parish of Willi Willi, County of Dudley, and, shortly after, Mr. C. Cullen collected from this parish and also the parish of Warbro a large number of undoubted Permo-Carboniferous forms. Mr. Dun (1898) added: "These were preserved mostly in limestone of which there appears to be a considerable development, both in thickness and area, and also in associated shales. This is as far as I am aware the first recorded instance of large deposits of Permo-Carboniferous limestone in New South Wales, though limestones are well developed in the underlying Carboniferous Beds."

Dr. W. G. Woolnough (1911) gave a preliminary account of the geology of the Kempsey district, but has not continued his investigations since then. He described the limestone at Willi Willi and Moparrabah and also the underlying glacial beds, and correlated them with those at Lochinvar in the Hunter Valley.

Carne and Jones (*Min. Res. N.S.W.*, No. 25. The Limestone Deposits of N.S.W.) described the limestone from the Macleay district, giving a number of localities in which it had been recorded, and including a sketch map of the deposits.

Sundry references to the Lower Palaeozoic rocks in the region have been made, chiefly by Dr. W. H. Bryan (1928), Mr. A. K. Denmead (1928) and Mr. E. C. Andrews (1900, 1908, 1928).

Professor Sir T. W. E. David (1932), on his geological map of the Commonwealth, marked the Upper Palaeozoic rocks of the Macleay as Lower Marine of the Kamilaroi System and the Lower Palaeozoic rocks north of the Kempsey area fault as Upper Silurian. He also showed Carboniferous rocks to the south of Kempsey.

Work carried out since 1928 has revealed many interesting facts, although paucity of outcrops has been a severe handicap. West of Yessabah it is difficult to do field work because of the prevalence of scrub. It is worthy of note also that in the more settled areas the excessive growth of paspalum grass in the summer and autumn makes mapping almost impossible. Lantana is unfortunately obtaining a hold in country which has been recently cleared and is an even worse obstruction than the stinging tree brush.

In view of the obstacles which impede the geologist in this luxuriant district it is little wonder that many problems are as yet unsolved.

The following table presents a summarized statement of the stratigraphy of the area and also some suggested correlations with rocks in other areas in Eastern Australia.

Age.	Name of Series.	Rock Types.	Maximum Thickness.	Correlation.
			Ft.	
Recent		River deposits, shell beds; estuarine, marine, aeolian deposits.	100+	
Pleistocene ..	Ridge Gravel.	Gravels, conglomerates, old river silts.	50	
Jurassic-Triassic	Clarence.	Fresh-water conglomerates, sandstones and shales with coal seams and fossil wood.	4,000+	Walloon Series. Bundamba Series. Ipswich Series.
Permian (?) ..	Kempsey.	Fresh-water tuffs, sandstones, shales, and conglomerates.	5,000+	
Permian ..	Macleay.	Marine conglomerates, sandstones, shales, limestones and tuffs. *Eurydesma cordatum* Zone.	3,400+	Hunter River: Kamilaroi, Lower Marine; Drake (N.S.W.); Silverwood (Qld.).
Carboniferous ..	Kullatine.	Fresh-water tuffs, slates, mudstones, conglomerates, and varves.	5,000+	Kuttung Series (N.S.W.).
Carboniferous ..	Boonanghi.	Arkose tuffs, mudstones, conglomerates with marine fossils.	4,000+	Burindi Series (N.S.W.).
Devonian ..	Hastings.	Dacites, quartzites, jaspers, banded chert, etc.	?	Barraba. Tamworth Series. Woolomin.
	Unconformity.			
Silurian (?) ..	Coff's Harbour.	Glassy cherts, quartzites, slates, phyllite and greywacke.	?	Neranleigh Series of Brisbane Schists.
	Unconformity ?			
Ordovician (?) ..	Nambucca.	Phyllites and slates.	?	Bunya Series of Brisbane Schists; Metamorphics of South Coast of N.S.W.

Stratigraphy.

A. Lower Palaeozoic Section.

Ordovician (?).

The Nambucca Series.

This section of the metamorphic rocks which outcrop over a large area between the Hastings and Clarence Rivers consists almost entirely of phyllites and slates which have been intensely folded. There is very little variety, the fine-grained texture persisting throughout.

The fresh rock is grey to bluish-grey in colour, but weathers readily to a buff or brown, owing to the oxidation of the iron content. It is fissile, cleaving parallel to the bedding planes, and the cleavage surface possesses a sheen due to the presence of mica flakes.

Fine exposures of contorted rock are seen in the road cuttings along the Oxley Highway east of Yarrowitch, and also at Nambucca Heads. As cleavage persists parallel to the lamination, corrugated slabs of the rock, now almost a schist, are obtainable.

Microscopically, the phyllite is very fine-grained and consists largely of quartz grains less than 0·01 mm. in diameter. Mica and chloritic material are also present.

The series as a whole is characterized by an extraordinary amount of milky quartz which occurs chiefly as concordant sheets parallel to the bedding planes, even when these are puckered. Sometimes it is transgressive, as irregular veins and reefs, which, near granitic intrusions, may contain a variety of materials. Iron pyrites, stibnite, mispickel, molybdenite, galena, cassiterite, gold and silver have been found. No fossils have been recorded so far from the series in the district examined.

Silurian (?).

The Coff's Harbour Series.

North of the Bellinger River there is a change in the rock type from the phyllites and slates of the Nambucca district. This is accompanied by a marked alteration in the strike from almost north-south to east-west.

Hard bands of chert, quartzite, and indurated slate are interstratified with phyllite. The cherts are hard, glassy, and bottle-green in thin fragments. They are strongly jointed, breaking into rhombs of about 20 cubic inches each. Quartzites are very diverse in colour, being black, white and green. Flakes of iron pyrites are sometimes common along the numerous small joint planes, as, for example, in the material used in the construction of the Coff's Harbour breakwater.

Denmead (1928) records greywacke from this series.

B. Middle Palaeozoic Section.

Devonian.

The Hastings Series.

This name has been used to include all the Devonian rocks in the Hastings district. It is possible that the equivalents of all Benson's New England Devonian Series are to be found.

The jaspers, quartzites and cherts may belong to the Woolomin Series. Banded cherts and spilites are of the typical Tamworth type. The mudstones present are in part Burindi, but some may be Barraba.

The rocks are only mentioned here for the sake of completeness, as Dr. G. D. Osborne hopes shortly to publish his views upon the structures south of the Hastings River.

Correlation of the Lower Palaeozoic Rocks with the Brisbane Schist Series.

Mr. A. K. Denmead (1928, p. 103) subdivided the Brisbane Schists into four groups as follows:

4. Fernvale Series.—Serpentines, jaspers, andesitic tuffs, banded cherts, shales, claystones and limestones.
3. Neranleigh Series.—Greywackes, banded slates, grits, boulder beds and quartzites.
2. Bunya Series.—Mica phyllites and quartz-mica schists with phosphatic cherts, slates and quartzites in the upper portions of the series.
1. Greenstones, probably altered porphyrites and basalts.

He adds: "No unconformities or disconformities are known to occur in the Brisbane Schists. The beds are all folded about north-north-west and south-south-east axes."

The greenstones (1) have not been found in northern New South Wales.

The description of the Bunya phyllites (2) given by Richards (1922) would apply equally well to those of the Nambucca Series. The presence of so much milky quartz, similarly disposed, is noteworthy, while the uniformity of both series and the parallelism of the strikes provide other links.

Denmead suggests that the Coff's Harbour greywacke may prove to belong to the Neranleigh Series (3). Quartzites and slates are common to both series, but the boulder beds have not been found in the southern locality.

The Hastings Series includes serpentines, jaspers, andesitic tuffs, banded cherts, shales, and claystones. This may be in part the equivalent of the Fernvale Series (4). Denmead has correlated his series with the Woolomin Series of Benson (1913). All are definitely Devonian in age.

With regard to the ages of the other series, David writes (1932, p. 44): "In Queensland the Bunya Series, presumably of Ordovician age, is formed chiefly of mica phyllites, having a thickness of perhaps as much as 18,000 feet. The *Diplograptus* which has been found on a horizon either at the top of this series or at the base of the Neranleigh Series (Silurian ?) may indicate an age either high in the Ordovician or low in the Silurian."

The similarity between the phyllites of the South Coast of New South Wales, described by Dr. Ida A. Brown (1928), and those of the Nambucca and Bunya Series has been noted in the field.

C. UPPER PALAEOZOIC SECTION.

The Upper Palaeozoic rocks described hereunder occur in the Parrabel Anticline and outcrop to the south of the Macleay River.

Lower Carboniferous.

The Boonanghi Series.

The lowest unit so far found in the Parrabel Anticline is a remarkable agglomerate resembling the Devonian Baldwin Agglomerate of Benson (1913). It is overlain, however, by a series of arkose tuffs, sandstones, and mudstones, with a few bands of conglomerate. The tuffs contain marine fossils, chiefly crinoid ossicles, but some corals, molluscs and brachiopods. The presence of *Loxonema* and *Rhipidomella* is sufficient to prove the Lower Carboniferous age.

Plant remains have been found in thin sandstone bands and among the marine shells. The total thickness must exceed 4,000 feet.

The following section was measured along the limb of an anticline going west from the Wittitrin Post Office:

	Thickness in Feet.
Blue Sandstones and Mudstones	225
Crinoidal Arkose Tuffs	110
Fine Conglomerate with Marine Shells	30
Blue Sandstone	170
Crinoidal Arkose Tuffs	100
Blue Sandstones	185
Arkose Tuffaceous Grit	45
Slates with Worm Tracks	100
Blue Sandstone	45
Grey Sandstone	240
Crinoidal Tuffaceous Grits and Sandstones	140
Mudstones and Sandstones	155
Crinoidal Arkose Grit	150
	1,695

The topmost beds have been faulted against the Kullatine Series. Slight faulting in the series has made further measurements unreliable, owing to the similarity of the rocks.

The crinoidal arkose tuff is usually greenish-grey in colour, with pink and white specks of felspar and calcite when fresh, but it weathers to a brown colour due to the decomposition of the ferro-magnesian minerals. The grainsize varies from an average of about 4 mm. in the coarser grits to about 0·05 mm. in the fine bluish tuffaceous sandstones. The microscope reveals beautifully twinned but slightly kaolinized basic felspar up to 3 mm. in length and an abundance of chlorite which is responsible for the green colour. Calcite, representing the crinoids, corals and shell fragments, is also present, but quartz is very rare. Evidently the basic volcanic ash settled down rapidly, without suffering much transportation, in a sea teeming with crinoids, corals and brachiopods.

Lower to Upper Carboniferous.

The Kullatine Series.

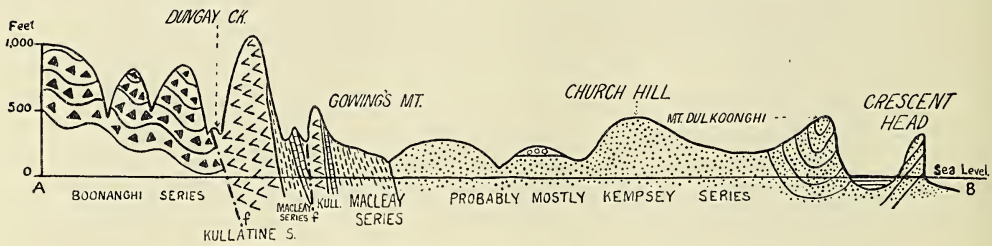
Faulted against the Boonanghi Series at Wittitrin are the lowest beds of the Kullatine freshwater series. These are sandstones, grits, fine conglomerates and interbedded acid tuffs which are overlain by thinly bedded slates and cherts containing *Rhacopteris* and large pieces of fossil wood.

The beds overlying the *Rhacopteris* horizon show abundant evidence of the presence of glaciers. About six hundred feet of heavy conglomerates and interbedded coarse grey tuffs contain dark grey varve shales showing the rhythmical banding. Boulders of igneous rock up to two feet across have been found in the conglomerates which are fluvio-glacial. Some of the boulders are angular and are definitely erratics. Typical rock types included in the conglomerate are: pink and grey granites, white quartz, quartzites, and many varieties of porphyries and sandstones. A tillite at the top of the series outcrops on the eastern side of Gowing's Mount.

The tuffs are generally more acidic than those of the Boonanghi Series. A thin section shows the presence of allotriomorphic quartz grains, but

subidiomorphic albite and orthoclase. Again there has been little transportation of the volcanic material. Quite a large proportion of chloritic volcanic ash occurs in patches throughout the rock.

The total thickness of the section is in doubt, owing to the lower portion being faulted away, and to the presence of numerous strike faults. It must, however, be in the vicinity of 5,000 feet.



Text-figure 1.—Section along line AB on map (Plate xvi).

Considering the distance from the type area for the Carboniferous in the Hunter valley and from the same series in the Werris Creek-Currabubula district, the resemblance of the Kullatine Series to the Kuttung Series is striking.

Especially is this seen in the glacial stage. A correlation of the conglomerates, varves and tillites in the three localities can hardly be disputed. This is important with reference to the views of Mr. J. H. Reid (1930) who considered rocks which he correlated with the overlying marine beds to be the marine equivalents of the Kuttung Series where it is not developed in Queensland. He was undoubtedly misled by Dr. Woolnough's (1911) statement: "The great interest and importance of the Upper Macleay Permo-Carboniferous is that the glacial beds do not appear to be the basal beds of the system, but seem to be underlain by a great but at present undetermined thickness of conformably bedded tuffs." These tuffs represent the upper beds of the Kullatine series and have associated conglomerates and varves.

It may be pointed out here that *Rhacopteris* was collected by Professor L. A. Cotton from an exposure several miles south of Kempsey. The exact locality of the occurrence is uncertain, but the writer is inclined to believe that the rocks from which the *Rhacopteris* was collected are equivalent to the Kullatine Series and must be quite distinct from the Kempsey Series (see below) which outcrops over a wide area south of Kempsey.

Lower Permian.

The Macleay Series.

Purple, red, green and blue calcareous shales overlie the Carboniferous glacial beds at Yessabah and Dondingalong. The correlation of these with the Lochinvar Glacial Beds at the base of the Kamilaroi System in the Hunter Valley, as suggested by Woolnough (1911), seems inevitable. Very good sections of these beds are to be seen in the road cuttings between Sherwood and Moparrabah. In places, granite and porphyry erratics up to two feet in diameter have been found. The more common pebbles are smaller and include granite, purple rhyolites, orthoclase-porphyries, quartz-porphyries, dacites, hornblende-andesites, glassy andesites, keratophyres, quartzites and sandstones. These are frequently faceted

and striated. Marine fossils are abundant in the shales. The thickness of the unit varies considerably, and sandstone and conglomerate bands appear.

Sandstones, mudstones and tuffs containing well preserved fossils including *Linoproductus springsurensis*, Fenestellidae, *Zaphrentis*, *Dielasma*, *Aviculopecten mitchelli*, and *Monilopora* follow.

These are overlain by the main limestone band which attains a thickness of 400 feet at Sebastopol. This is the *Eurydesma cordatum* horizon, but is made up largely of the remains of crinoids. *Trachypora wilkinsoni*, *Monilopora*, Fenestellidae and small brachiopods have been found. The rock is crystalline, fairly even in texture throughout, and is coloured pink, reddish-brown, purple and grey but is very often white.

The limestone is followed by a succession of hard silicified limestone bands which weather to brown spongy masses. Silica has replaced the *Monilopora*, *Spirifer* and a large *Pecten*, which are plentiful.

Soft sandstone and mudstone make poor outcrops in the eastern areas, but the section below was measured in the Willi Willi district in a northerly direction along Warbro Brook. The beds dip in a northerly direction at 25 degrees.

	Thickness in Feet.
Mudstones	500
Tuffaceous Mudstones and Conglomerates	400
Grits and Sandy Tuffs	100
Fossiliferous Mudstone	100
Flaky Yellow Shale	100
Limestone (Impure band)	50
Purple and Green Shales	100
Mudstone	180
Chert and Tuff	45
Soft Sandstone (*Strophalosia*)	55
Silicified Limestone (with *Monilopora*)	85
Silicified Sandstone	50
Silicified Limestone	55
Crinoidal Limestone (*Eurydesma cordatum*)	310
Sandstones and Mudstones	195
Conglomerates and Sandstones	175
Fenestellidae Cherts and Tuffs	120
Sandstones and Conglomerates	110
Fenestellidae Mudstones and Sandstones	160
Glacial Beds	500?
	3,390

Rudder's Hill, near the new entrance of the Macleay, is composed of some hundreds of feet of slate, sandstone and conglomerate. Woolnough (1911) suggested that the latter might be fluvio-glacial in origin. *Aviculopecten* cf. *mitchelli*, Fenestellidae, and other Permian fossils have since been found in the other slates below this. The whole series has been hardened by the intrusive rocks nearby. Between Clybucca and Barraganyatti a series of sandstones and shales dipping steeply to the north-west contains marine fossils, probably Permian. Crinoid stems and shells have been found by Dr. G. D. Osborne in sandstones exposed in a road cutting near Blackman's Point.

Pending a more definite identification of the fossils collected, all the occurrences of marine beds have been referred to the Macleay Series.

Permian (?).

The Kempsey Series.

Owing to the discontinuity of outcrops east of Dondingalong, it has not been possible so far to work out the geological structures. It would appear that most of the area is occupied by sandstones and tuffs with unidentified plant remains, which have been grouped under the name of "Kempsey Series".

The Kempsey Series appears to follow the trend of the Parrabel Anticline from Willawarrin to Kempsey but has not been satisfactorily separated from the soft marine beds at the top of the Macleay Series (Lower Permian)—a fact which indicates a Permian age for part at least.

Criteria used for the identification of the Kempsey Series are as follows: (1) Characteristic lithology of tuffs, sandstones and shales; (2) rhythmical deposition always marked; (3) abundant and typical shale (?) inclusions; (4) abundant but unidentifiable plant remains; (5) arrow-head markings; and (6) generally poor outcrops.

There is a great variation in the lithology of the sandstones and tuffs in colour, texture and composition, but recognition of any of them is rarely difficult. There is a certain relationship between the sediments in each locality in which they have been examined but the rhythmical deposition is universal. At Crescent Head there are alternating beds of dark sandstone and sandy tuff, usually a couple of feet in thickness. The texture varies greatly, some conglomerate bands being present. About Kempsey the tuffs are lighter in colour and there is more sandstone. Although there are some thicker bands of tuff, as at Church Hill, it is more common to find beds a foot or less thick. The rhythm is again seen at Smoky Cape, where there is some resemblance to the tuffs about Kempsey. At Racecourse Head, Delicate Nobby and the Big Hill, thin bands of mudstone, claystone and tuff occur.

Irregular and abundant inclusions of what appears to be grey shale are especially noteworthy in the Kempsey stage. They are usually in a fine-grained sandstone and suggest intraformational breccias.

Woolnough (1911) noted the plant remains at Crescent Head. These are especially abundant on some horizons in all the localities cited, and indicate the freshwater origin of the series.

A feature peculiar to the Kempsey Series is what has been called the "Arrow-head marking" which appears as a succession of Vs, one inside the other, when the rock is split parallel to the lamination. The cross section is circular. The only occurrence seen outside the series was in some mudstones low in the Boonanghi Series (Lower Carboniferous). How the marking was formed, what it represents, and its value as a criterion for stratigraphical purposes are questions not yet solved. It may be worm track, plant impression, or the result of some physical phenomenon.

A massive conglomerate, at least 500 feet thick, at Korogoro Point, overlies rhythmically-bedded tuffs and sandstones at Mt. Dulkoonghi. Woolnough (1911) believed that the conglomerate might be Trias-Jura in age, but as it resembles smaller bands in the Kempsey Series, it is retained there for the present. It occupies the centre of a syncline running north and south at Mt. Dulkoonghi, dipping north towards Korogoro Point where it attains its maximum development.

Referring to rocks which have been included under the Kempsey Series, Woolnough did not offer suggestions with regard to their age but stated: (*a*). "On the east, the Silurian rocks [Nambucca Series. A.V.] are bounded by

a series of contorted and cleaved quartzites and slates which we may refer to as the Kempsey Slates. The boundary appears to be near Hickey's Creek where a heavy conglomerate is met with. In the road sections between Hickey's Creek and Kempsey, the slaty rocks exhibit dips in all directions and there does not seem to be any well defined axis of folding." (*b*). "On the coast between Smoky Cape and South West Rocks what appear to be the equivalents of the Kempsey slates occur in broad undulations but with approximately horizontal disposition as a whole. They are black in colour and intensely hard as a result of contact metamorphism."

The conglomerate at Hickey's Creek is probably Pleistocene, similar to that at Sherwood. It unconformably underlies the older series.

It is likely that it was the highly folded Kempsey Series which influenced earlier observers in marking the area about Kempsey as Devonian and Silurian (C. S. Wilkinson, 1880; E. F. Pittman, 1892). There is even now a slight possibility that they might be Upper Devonian, but the large plant stems render this unlikely. Dr. G. D. Osborne suggested that the Crescent Head rocks might be Lower Carboniferous in age, while the conglomerate at Mt. Dulkoonghi reminded him of the Greta conglomerate of the Hunter Valley.

The position of the series in relation to the Parrabel Anticline and the fact that it is a thick unit not represented in the neighbouring sequence from Lower Carboniferous to Lower Permian suggest a Middle Permian age.

The question must be left until more detailed work is undertaken.

D. MESOZOIC.

Triassic to Jurassic.

The Clarence Series.

Some 27 miles south of Grafton the main North Coast road from Woolgoolga climbs an escarpment composed of sandstones and coarse quartz-pebble conglomerates which have the appearance of estuarine beds. They include shale bands containing well preserved plant remains. Just north of Dirty Creek a horizon of fossil wood, strongly reminiscent of the basal beds of the Walloon Series at Warwick, Queensland, occurs. Seams of carbonaceous shale and coal overlie these, then follows a thick series of sandstones.

With regard to the age of the Clarence Series Dr. A. B. Walkom (1918, p. 84) wrote: ". . . the fact that Carne (1908) indicates the presence of *Taeniopteris spatulata* (*T. Daintreei*) in the lower part of the series, is sufficient to render the correlation of any part of the Clarence Series with the Ipswich Series improbable. It is possible that the sandstones and conglomerates at the base of the Clarence Series may be the equivalents of the Bundamba, but, on the present evidence, I believe the greater part of the Clarence Series (if not all of it) is to be correlated with the Walloon Series of Queensland."

As the Grafton bore (3,070 feet) met coal seams, probably of the Ipswich Series, and did not reach the underlying Palaeozoic rock (David, 1932), it seems that the beds described above have overlapped the older series and that there is still a possibility that the three Queensland divisions are represented.

E. CAINOZOIC.

Pleistocene.

Ridge Gravels.

Extensive deposits of boulders and quartz gravel cap hills on the north and south banks of the Macleay River and are also found at Macksville on the

Nambucca River. At Sherwood, rounded jasper, quartz, chert and quartzite pebbles up to six inches in diameter form a conglomerate. This was thought by Woolnough (1911) to be Permo-Carboniferous in age—a tribute to the degree of cementation. The deposit unconformably overlies the steeply dipping Macleay Series. The age of the gravels has been determined by reference to the physiography. They have been spread out on the floor of a valley carved out of the tableland which was uplifted at the close of Tertiary times (Andrews, 1912). Since their deposition the Macleay River has become entrenched in the old valley, probably through a minor uplift towards the close of the Pleistocene. Thus it seems that the gravels were laid down during Pleistocene times.

Recent.

(i). *Estuarine Deposits.*—Below the recent sand and alluvial deposits which form the Lower Macleay flats are estuarine sands, muds and clays with some shell bands. *Spisula trigonella* and *Arca trapezia* are the chief forms and prove the estuarine origin of the sediments. The Clybucca Drainage Works revealed a bed of shells which must underlie 25 square miles of flats. A bore at Smithtown gave the following section:

	Feet.
Sub-soil	3
Silty Clay	13
Sand Drift with Shells	28
Yellow Clay	9
Mudstone and Pipeclay	9
Sand Drift with Shells	2
Mudstone and Pipeclay	11
Pipeclay	5
Total Thickness	80

The bore was started 9 feet 3 inches above the average river level, and struck shales at 80 feet below the top of the bore. The sediments have been laid down since the rise in sea-level which drowned the valleys along the coast.

(ii). *Marine Deposits.*—Some of the sediment forming the sandy flats along the coast as well as that of the sand and boulder beaches is marine in origin.

(iii). *Freshwater Deposits.*—The coastal rivers have built terraces of alluvium and gravel, and these freshwater sediments cover large areas, especially near the coast. In swampy districts, notably at Clybucca and Collombatti, there has been a slow accumulation of peat and clay.

(iv). *Aeolian Deposits.*—Sand has been blown over much of the coastal flats sometimes forming hills. It is often well mixed in with swamp muds and alluvium. On the south side of Smoky Cape it has accumulated to a height of nearly two hundred feet. A sand deposit, partly consolidated, covers the hills at Korogoro Point and the sand has been piled high on the southern and south-western sides.

IGNEOUS ROCKS.

(a). Carboniferous.

Serpentine.

The Port Macquarie serpentine is in all probability coeval with the New England occurrences of this rock, as described by Benson in 1913 (Browne, 1929). It outcrops along the coast between the Hastings River Entrance and Tacking Point, and strikes 10 degrees north of west in that locality, being nearly two

miles in width. The road cuttings along the Oxley Highway west of Wauchope reveal much of this beautiful rock. It varies greatly in colour and texture, and is sometimes silicified, giving rise to quartzites and jaspers. Kernels of the unaltered basic rock are common, while veins of magnesite and asbestos are present. The serpentine invades the cherts, slates and mudstones of the Hastings Series (Devonian).

(b). Late Permian.

The Granites and Porphyries.

"The earth-movements which affected the Permian rocks near the close of the Palaeozoic era along what is now the east coastal portion of Australia were accompanied by extensive plutonic intrusions" (David, 1932, p. 70).

The granites and porphyries which intrude Upper Palaeozoic rocks at Smoky Cape and Lower Palaeozoic rocks at Mt. Yarrahapinni are probably all of late Permian age.

Woolnough (1911) described the Laggers' Point granite. It only remains to mention that in thin section quartz, orthoclase, biotite, plagioclase, and a little iron pyrites were seen. Numerous roof pendants and inclusions of the intruded tuffs and slates are present. There appears to have been some contamination of the granite by a large inclusion of slate at Little Bay.

Woolnough mentioned sills of light and fine-grained felsitic rock connected with the granite. Point Briner at South West Rocks is composed of a porphyritic phase of this rock which proves to be a granophyre. The fresh rock is a sparkling white, but it weathers to a pale orange colour. Phenocrysts of quartz and orthoclase reach three-eighths of an inch in diameter. The granophyric structure of the groundmass is striking when seen under the microscope. The pattern, developing outwards from the phenocrysts, becomes progressively finer and ultimately gives way to a mosaic of interlocking quartz and orthoclase grains.

(c). Tertiary.

Basalts.

Great thicknesses of basalt cover the Dorrigo Plateau and Hastings Ridge to the north and south of the Macleay Valley. Woolnough (1911) records a capping of basalt some hundreds of feet in thickness resting on Lower Palaeozoic slates at Anderson's Peak, near Bellbrook.

Structural Geology.

1. Lower Palaeozoic Trends.

The metamorphic rocks outcrop from the basalt-capped Hastings Ridge in the south to the Clarence River in the north, while the New England granite bathylith which invades them forms the irregular western boundary. They are overlain by Mesozoic sediments in the north-east with a well-marked unconformity and by Upper Palaeozoic sediments in the south-east. Their relationship to the latter has not been directly ascertained, but it must surely be an unconformable one.

The trend is from north-north-east to north-north-west, south of the Bellinger River, being roughly parallel with that of the Brisbane Schists, but swings round north of Urunga to east-west. Here the beds are almost vertical and it seems that there is a series of tightly folded anticlines and synclines, but there may be several different horizons of chert and quartzite.

Bryan (1928), dealing with the Brisbane Schist Series, wrote: "This very extensive series of metamorphic rocks is almost continuous from Tweed Heads to north of Rockhampton. The Coff's Harbour schists in northern N.S.W. although out of alignment with the Queensland formation, are regarded by most geologists as being part of the same series, the lack of alignment being due to a lateral break—a drag of the rocks for about 150 miles in a direction at right angles to the strike. The series has an enormous thickness." As there is a change in the nature of the rocks coincident with the change in strike, it seems that much more work will have to be done before the reasons for this important structural break are ascertained.

The excessive alteration, puckering, and folding of the Nambucca Series is evidence of a period of intense diastrophism which took place before the Devonian rocks were laid down, since these are much less affected.

2. The Upper Palaeozoic Anticline.

The dominant structure in the southern portion of the area examined has been called the Parrabel Anticline. Into it have been folded the Upper Palaeozoic strata from Lower Carboniferous at least to Lower and probably Middle or Upper Permian. The northerly plunge of the anticline gives rise to a general semicircular outcrop of the units, and this is reflected in the topography.

Within the major structure there is considerable folding, although, towards the core, the Boonanghi Series is much more gently folded than the younger Kullatine and Macleay Series. These Lower Carboniferous rocks to the west of Wittitrin form anticlines and synclines trending north and south, and dips rarely exceed 10 degrees. There is a zone of strike faulting in the Kullatine Beds between Wittitrin and Yessabah, but the throw of the faults is not very great. A relatively large one has placed the series against the Boonanghi marine beds, giving a doubtful relationship between the two series; the strikes, however, are parallel on either side of the fault.

The Kullatine and Macleay Series in that neighbourhood are dipping steeply and are sometimes vertical or even overturned. Besides the strike faulting, two main oblique fractures have developed, and there has been some dragging of the limestone and its associates along the fault planes. At Willi Willi and Moparrabah, near the nose of the anticline, there has been less disturbance, and the rocks dip in a northerly direction at 25 degrees.

In view of the gently folded Mesozoic sediments in close proximity to Permian rocks, which have been intensely folded in the Drake District (Andrews, 1908) further to the north, it seems certain that the folding and faulting took place during late Permian times. The limits are Middle Permian and Lower Triassic, but the late Permian orogeny is recognized elsewhere (Reid, 1930; David, 1932; etc.). In view of the apparent conformity throughout the Upper Palaeozoic succession in the Parrabel Anticline, there does not appear to have been any diastrophic epoch between Lower Carboniferous and Late Permian times.

3. Faults.

David (1932) marks the junction between the Upper and Lower Palaeozoic rocks in the Macleay District as the Kempsey Area Fault. This seems to be a necessary inference in view of the difference in strikes and the fact that Permian rocks meet the Ordovician (?) without intervening Carboniferous.

Details of the fault have not been ascertained, but the junction between the series has been found near Toorooka on the Macleay River and also about three miles south of Eungai railway station. The faulting post-dated the folding of the Parrabel Anticline, as it truncates this structure. It probably occurred before the deposition of the Mesozoic sediments on the older series where Permian sediments may have been.

Denmead (1928) reports several east-west faults breaking across the strike of the Brisbane Schist Series. The Kempsey Area Fault may be contemporaneous with these. Denmead notes that some of the faulting in the Brisbane River zone is post Mesozoic, but considers the great dip-faults to be pre-Mesozoic and probably coeval with the block faults at Silverwood, Gympie and other places.

4. Igneous Intrusions.

The New England bathylith has invaded the sediments to the west. Probably contemporaneously a number of smaller intrusions occurred nearer the coast. These are chiefly in the nature of bosses and dykes.

Granite bosses are found at George's Creek (Woolnough, 1911), Smoky Cape (Woolnough, 1911), Mt. Yarrahapinni, and near Valla. Roof pendants at Smoky Cape indicate that erosion has only recently exposed this granite mass.

The age of the intrusion has been determined as post-Permian and pre-Mesozoic as the igneous rock invades Permian sediments at Rudder's Hill, Drake, Rivertree and Silverwood, and is overlain by Mesozoic sediments in the Silverwood district. It is possible, of course, that some of the granites may be older. The invasions occurred soon after the folding and faulting of the rocks at the close of Permian times.

5. The Mesozoic Basin.

Some distance to the north of Woolgoolga, near Corindi Creek, conglomerates and sandstones unconformably overlie the Lower Palaeozoic rocks and form the southern margin of the Clarence Basin. They dip in a north-westerly direction at 5 degrees. These beds are not the lowest of the sequence, but represent an overlap probably of the Bundamba Sandstones upon the Ipswich Coal-Measures (Triassic). The Jurassic Walloon Series overlaps the Bundamba Sandstones to the north and outcrops over a large region in southern Queensland. The Clarence Basin must have formed during the Triassic and was raised at the close of Jurassic times, as no Cretaceous sediments are represented.

Geological History.

The fine-grained sediments of an Ordovician sea, covering most of what is now Eastern Australia, were subjected to intensive folding and metamorphism, probably before the deposition of more variable Silurian rocks. Both series, at any rate, were folded along north-south axes prior to the development of a Devonian sea which covered most of New South Wales. It is possible that there was a land area between Coff's Harbour and the Queensland border.

Deposition continued with little interruption until well into Permian times. In common with the central districts, there was a change in the north from marine to freshwater conditions at the close of the Lower Carboniferous, but a return was made ushering in the Permian.

Violent volcanic eruptions persisted throughout the entire period during changing climatic conditions. The advent of glaciers towards the close of

Carboniferous times is demonstrated by the varve shales and tillites, while striated pebbles occur in the Lower Permian beds.

It seems that there was a freshwater lake in existence in the Macleay District during Middle Permian times.

At the close of the Permian occurred a most important diastrophic epoch which folded and faulted the Upper Palaeozoic sediments. This was closely followed by invasions of granite bringing a great variety of minerals.

Erosion during early Triassic times exposed the granites, removing the sedimentary covering. A transgression in the north of the area led to the deposition of the Clarence Series, and it was not until the close of the Jurassic that these were raised above sea-level.

Then came a long period of erosion giving rise to the formation of a Tertiary peneplain, but leaving a Main Divide at several thousand feet. The Kosciusko Uplift at the close of Tertiary times added another two thousand feet to this, leading to the rejuvenation of the streams and the development of canyons.

Earth and sea movements since have been of minor importance.

Conclusion.

Palaeontology and physiography have received scant attention in this paper because both are of sufficient importance to be treated separately. The aim of this discussion has been to present in as systematic a form as possible the broader aspects of a large area of hitherto neglected country. It will provide a basis for future work in an area which is destined to cast some light upon problems which have worried both New South Wales and Queensland geologists.

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EXPLANATION OF PLATE XVI.

Geological Map of the Middle North Coast of New South Wales.